Mottier & Bell

A study of the loss of head in gate valves

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A STUDY OF THE LOSS OF HEAD IN GATE VALVES

BY

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AND

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FOR THE

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This is to certify that the thesis prepared in the Department of Theoretical and Applied Mechanics by CHARLES MANLY BELL and CHARLES HALVATIOUS MOTTIER entitled A Study of the Loss of Head in Gate Valves is approved by me as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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INTRODUCTION.

The subject of this thesis was selected as one on which very little data was as yet available. After a long search for information on the subject it was found that four men had conducted experiments on the flow of water through gate valves. These four were Weisbach, Kuichling, Folwell and Thomas.

Weisbach conducted his experiments about thirty years ago on small valves up to about 2-1/2 inches in diameter; Kuichling investigated a large valve 24 inches in diameter; Folwell made a few experiments on a 4 inch gate valve and Thomas in a thesis for the degree of Bachelor of Science at the University of Illinois in 1906, tested one inch and two inch valves for the cause of loss of head. In view of the fact that nothing was as yet known regarding the loss of head in gate valves between 4 inches and 24 inches we decided to concentrate our efforts on valves 6 inches and over in diameter and if possible determine a law that would cover in a general way all sizes of valves.

The experiments were conducted in the Hydraulics Laboratory of the University of Illinois which has excellent facilities for carrying on such experiments.

METHOD OF EXPERIMENT.

Pressure was obtained from the sixty foot stand-pipe in the Laboratory, the level of water being kept constant at any height by a Snow Steam Pump with a Fisher altitude govenor.

The water flowing from the stand-pipe, through the valve to be tested was discharged into a sump, from which it was again pumped into the stand-pipe. Thus the same water was used over and over again.

A 6 inch valve made by the Ludlow Valve Manufacturing Co., was first selected. The pipe leading from the valve emptied into an orifice box 4 ft. x 4-1/2 ft. x 6-1/2 ft. inside measurements, the valve being 2 ft. 6 in. from the end of the pipe which discharged into atmospheric pressure. A Bourdon gage was connected 6 in. below the valve, the reading on the gage giving the pressure head, which added to the elevation head gave the head lost in the valve and pipe. The head on the orifice was measured by a calibrated tube on one side of the box and the quantity calculated from the formula,

$$q = c F \sqrt{2 g H}$$

in which q is the quantity in cu. ft. per second, F the area of the orifice, H the height of water above the center of the orifice in feet, g the acceleration of gravity or 32.2 feet per second per second and c a constant depending upon the shape of the orifice and the height of water. The value of c was taken from tables in Merrimans Hydraulics. After a large number of readings had been

taken with the six inch orifice it was found that this size was not large enough to perform the experiments. It was therefore decided to abandon this method of procedure and adopt another which will now be described.

Another 6 inch valve made by the same company and situated on the south side of the basement of the laboratory was selected because it could be made to discharge into a large measuring pit about 5 feet and 8.02 feet in depth and diameter. The pipe on both sides of the valve for a considerable distance was horizontal which eliminated the necessity of taking into account any loss due to elevation. Two 1/4 inch holes were drilled in the pipe, one 2 feet above the valve and the other 18 feet below the valve. Into each hole was inserted a connection to which was attached a Bourdon gage. The elevation of the water in the pit was taken by means of a level rod at the beginning and end of a certain interval of time. The rod was first set at a certain point, the time being recorded when the water reached the rod. It was then raised a known distance and the time noted when the water again reached it. An ordinary Elgin watch was used to catch the time. The rate at which the water was discharged from the pipe was determined by multiplying the rise of the water by the cross-section area of the pit and dividing this result by the time. The loss of head in the pipe alone between the two pressure gages due to friction was calculated from Merriman's tables. The difference in the reading of the two pressure gages, after the loss in the pipe had been deducted, gave the loss due to the valve alone. The best method which we knew of to determine the percentage of opening of the valve was by finding the number of the

turns necessary to open the valve entirely and then count the number of turns each time a reading was taken. The number of turns necessary to open the valve completely was found to be 14-1/2. The valve was taken apart and it was found that 3 turns would open the valve 1 inch. Owing to the fact that the valve was forced into a seat after the opening was closed it was necessary to determine the number of turns required to raise the valve from its seat to the position at which water would just begin to flow. To obtain this, a 1/4" hole was bored in the bottom of the pipe just below the valve. The valve was then opened very slowly and the number of turns noted at just the moment the water ran out of the hole. This distance was found to be 1-7/8 turns. It was found that the valve could be turned 12-7/8 turns from this point. We therefore assumed the extra 7/8 turn to be used in pulling the gate up into the hood of the valve. Measurements taken when the valve was apart checked our supposition and our observations. Before each reading was taken the valve was opened from a closed position to the required opening so as to avoid any motion lost in the backward turn of the valve. The number of turns in the tables and curves is the number from the point at which water just began to flow.

These results when plotted appeared to be inaccurate or at least did not follow any uniform law. It was therefore decided to discard these results and adopt more efficient methods of measurement. A stop watch was used in place of the ordinary watch to determine the exact time of flow in the pit. In the first experiments a great deal of difficulty was experienced in observing the elevation of water in the pit. The pipe discharging into one side of the pit

in an almost horizontal direction with a high velocity caused a swirling motion which in turn caused the water to rise on the sides of the pit higher than in the center. This was overcome in the later experiments by using a curved pipe which discharged the water vertically downward into the pit. The Bourdon pressure gages were discarded and in their place was used the differential pressure gage shown in the diagram Figure The gage consisted of a U-tube half full of mercury. A rubber tube connected the top of one side of the gage to the pipe, being attached to the pipe 2-1/2 feet back of the center of the valve. A tube connected the top of the other side of the gage with the pipe 18-1/2 feet beyond the center of the valve. A stop cock was placed at the top of each side of the gage to permit any air to escape from the tubes. The scale was graduated to read the difference in pressure directly in feet. With these changes, the rest of the experiments were carried on and resulted in accurate data.

FIG. 1.

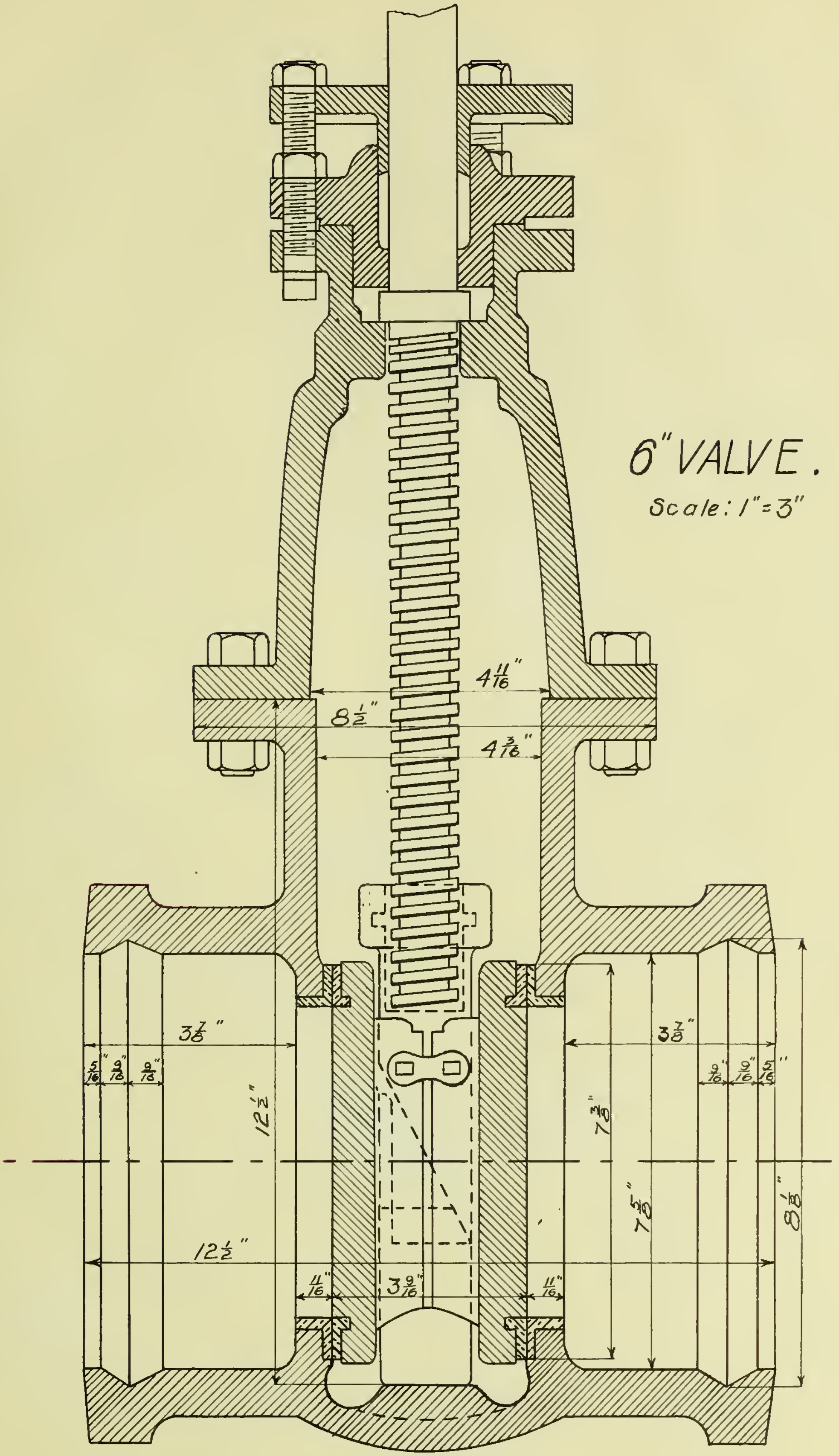
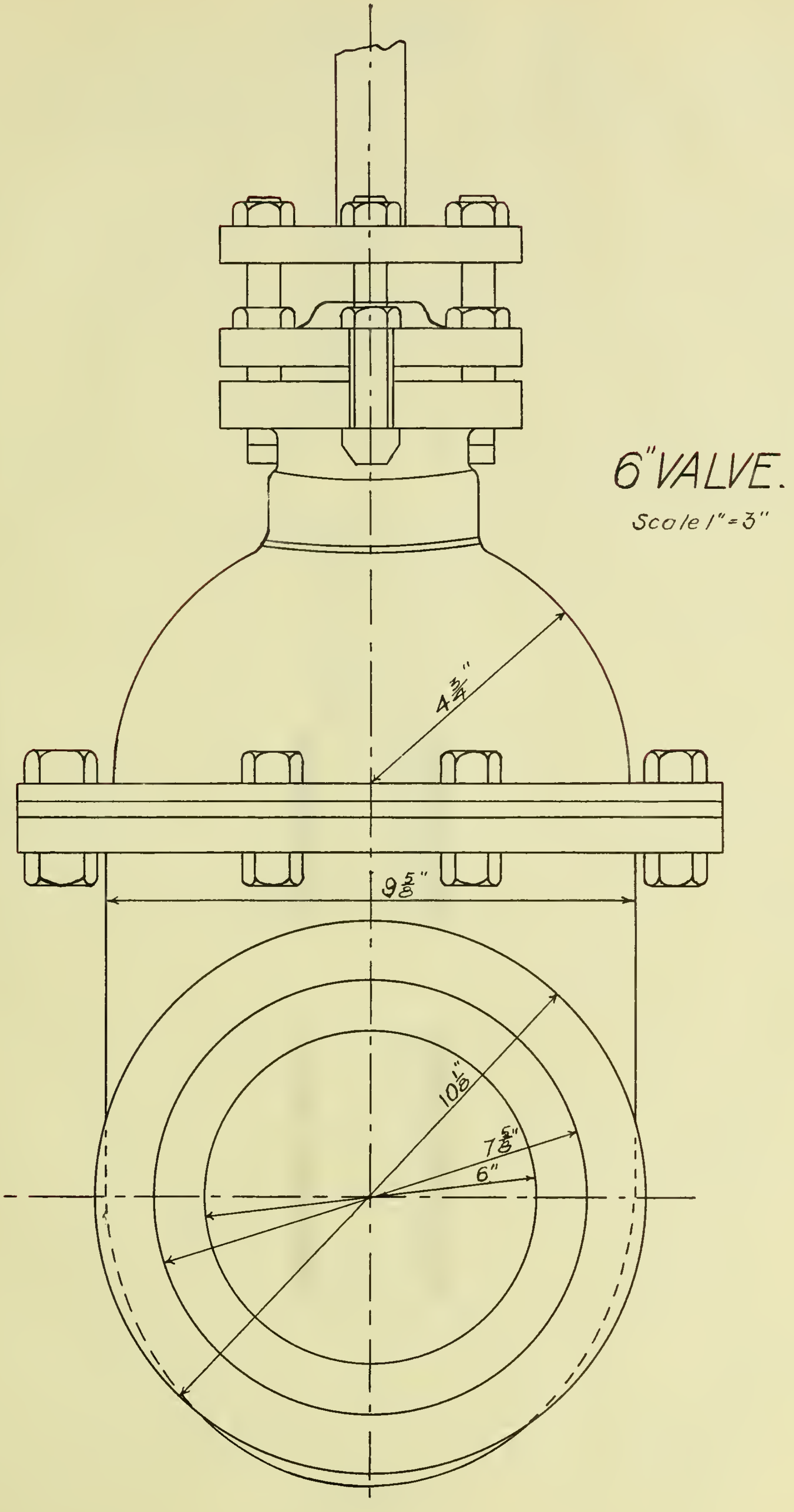

6" VALVE.
Scale: 1" = 3"
$4\frac{11}{16}$"
$8\frac{1}{2}$"
$4\frac{3}{16}$"
$3\frac{7}{8}$"
$3\frac{7}{8}$"
$\frac{5}{16}$" $\frac{9}{16}$" $\frac{9}{16}$"
$\frac{9}{16}$" $\frac{9}{16}$" $\frac{5}{16}$"
$12\frac{1}{2}$"
$7\frac{3}{8}$"
$7\frac{5}{8}$"
$8\frac{1}{8}$"
$12\frac{1}{2}$"
$\frac{11}{16}$"
$3\frac{9}{16}$"
$\frac{11}{16}$"

FIG. 2.



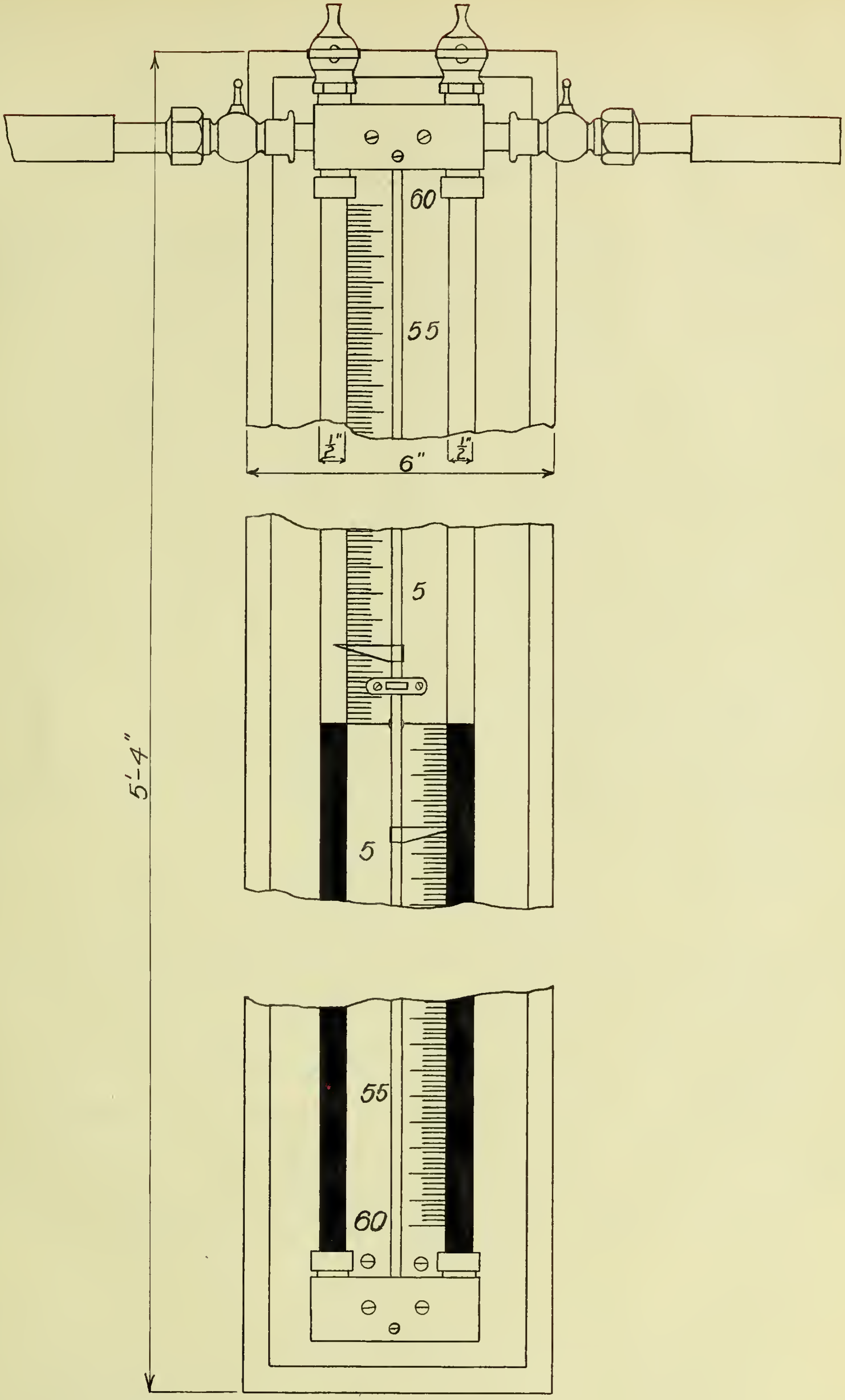


FIG. 3.

RESULTS AND CONCLUSIONS.

The average values of "m" in the equation $H = m \frac{v^2}{2g}$, as calculated from those in tables II and III, as well as those obtained by Kuichling and Weisbach in their experiments referred to in the introduction to this thesis are shown in the following table.

	Size of Valve	Ratio of Height of Opening to Diameter of Pipe							
		1	7/8	3/4	5/8	1/2	3/8	1/4	1/8
Kuichling	24"	0	—	1.0	1.5	3.3	8.6	22.7	75.5
Weisbach	2"	0	.07	0.26	0.81	2.1	5.5	17.0	98.0
Plate II	6"	1.0	1.1	1.4	2.5	4.0	8.7	21.0	116.0
Plate IV	8"	0	0.3	0.6	1.1	2.7	6.9	21.2	122.0

Plate V shows the agreement between the values found in these experiments and those of Weisbach and Kuichling.

These experiments also show the action of the valve in stopping the flow of water. It is seen from Plate V that very little loss takes place until the valve is 3/4 closed. Beyond this point the loss increases very rapidly until the valve is completely shut. This shows that the valve can be over 3/4 closed before any appreciable effect is noticed upon the flow of water through it.

TABLE I

DATA SHEET for 6" VALVE USING BOURDON GAGES

No. of turns necessary to open valve = 12

$H = m\frac{V^2}{2g}$

Area of Pit = 51.54 sq.ft.; of pipe = .1964 sq.ft.

Test No.	No. of Turns of Valve	Gage Readings: Gage No 463 ft.	Gage No 458 ft.	Gage No 463 Corrected	Gage No. 458 Corrected	Difference in Readings	Rod Readings: Initial ft.	Final ft.	Difference ft.	Time Secs.	Discharge Cu. ft. per Sec.	Velocity Ft. per Sec.	Loss in Friction in Pipe ft.	Loss in Valve ft.	m $\left(\frac{H}{\frac{V^2}{2g}}\right)$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1/2	18.4	0	19.0	0										
		18.0	0	18.5	0	18.7	9.9	8.4	1.5	401	.193	.982	.013	18.7	1330
14	1/2	25.5	0	25.9	0										
		25.4	0	25.8	0	25.8	10.3	8.3	2.0	510	.202	1.02	.014	25.79	1720
26	1/2	31.1	0	31.2	0										
		29.2	0	29.5	0	30.4	10.9	7.7	3.2	737	.224	1.14	.0186	30.38	1520
37	1/2	39.8	0	39.8	0										
		39.2	0	39.2	0	39.5	10.3	8.1	2.2	439	.259	1.32	.0148	39.35	1400
48	1/2	35.1	0	35.2	0										
		35.1	0	35.2	0	35.2	9.6	7.9	1.7	370	.237	1.21	.0157	35.18	1550
2	1 1/2	15.7	0	16.3	0										
		16.2	0	16.7	0	16.5	9.6	8.1	1.5	131	.591	3.01	.131	16.4	116
15	1 1/2	22.1	0	22.5	0										
		21.8	0	22.3	0	22.4	10.4	7.4	3.0	217	.715	3.64	.195	22.2	106
27	1 1/2	26.1	0	26.0	0										
		25.5	0	25.5	0	25.7	10.8	7.6	3.2	212	.779	3.97	.223	25.5	106
38	1 1/2	34.8	0	35.0	0										
		34.5	0	34.6	0	34.8	9.5	7.2	2.3	143	.830	4.23	.256	34.54	125
49	1 1/2	31.0	0	31.2	0										
		30.7	0	31.0	0	31.1	9.7	7.2	2.5	153	.840	4.28	.259	30.8	110

TABLE I (cont'd)

Test No.	No. of Turns of Valve	Gage Readings: Gage No. 463 ft.	Gage No. 458 ft.	Gage No. 463 Corrected	Gage No. 458 Corrected	Difference in Readings	Rod Readings: Initial ft.	Final ft.	Difference ft	Time Secs	Discharge Cu.ft. per Sec.	Velocity Ft. per Sec.	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3	2½	13.0	0	13.6	0										
		13.0	0	13.6	0	13.6	9.0	7.5	1.5	80	.967	4.92	.346	13.30	35.7
16	2½	17.2	0	17.8	0										
		17.0	0	17.5	0	17.7	10.0	7.5	2.5	120	1.072	5.45	.422	17.30	37.8
25	2½	3.1	0	3.4	0										
		2.2	0	2.5	0	2.8	9.5	7.5	2.0	218	.474	2.41	.835	1.965	22.0
28	2½	20.4	0	20.7	0										
		18.6	0	19.0	0	19.8	9.8	7.3	2.5	105	1.228	6.25	.561	19.24	31.8
39	2½	27.5	0	27.5	0										
		27.5	0	27.5	0	27.5	9.8	7.5	2.3	85	1.395	7.10	.724	26.80	33.1
50	2½	23.8	0	23.9	0										
		23.8	0	23.9	0	23.9	9.4	7.4	2.0	77	1.34	6.80	.664	23.20	32.4
4	3½	8.9	0	9.5	0										
		8.9	0	9.5	0	9.5	8.7	7.2	1.5	63	1.228	6.24	.561	8.90	14.7
17	3½	12.5	0	13.1	0										
		12.5	0	13.1	0	13.1	10.0	7.5	2.5	99	1.302	6.62	.640	12.46	18.0
29	3½	16.0	0	16.5	0										
		15.0	0	15.5	0	16.0	10.0	7.3	2.7	91	1.530	7.79	.880	15.10	15.9
40	3½	21.0	0	21.0	0										
		21.0	0	21.0	0	21.0	9.8	7.4	2.4	74	1.670	8.50	1.040	19.96	17.5
51	3½	18.9	0	18.9	0										
		18.9	0	18.9	0	18.9	9.2	7.2	2.0	63	1.640	8.35	1.000	17.90	16.6

TABLE I (cont'd)

Test No.	No. of Turns of Valve	Gage Readings: Gage No 463 ft.	Gage Readings: Gage No 458 ft.	Gage Readings: Gage No 463 Corrected	Gage Readings: Gage No 458 Corrected	Gage Readings: Difference in Readings	Rod Readings: Initial ft.	Rod Readings: Final ft.	Rod Readings: Difference ft.	Time Secs.	Discharge Cu. ft per Sec.	Velocity Ft. per Sec	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
5	4½	6.6	0	7.0	0										
		6.7	0	7.1	0	7.1	8.8	7.3	1.5	58	1.332	6.78	.659	6.40	9.0
18	4½	10.0	0	10.6	0										
		10.0	0	10.6	0	10.6	9.8	7.5	2.3	75	1.580	8.04	.931	9.70	9.7
30	4½	13.0	0	13.5	0										
		13.0	0	13.5	0	13.5	9.5	7.3	2.2	66	1.720	8.75	1.100	12.40	10.4
41	4½	16.4	2.0	16.0	2.0										
		16.0	2.0	15.9	2.0	14.0	9.8	7.4	2.4	64	1.930	9.80	1.380	12.60	8.5
6	5½	4.8	0	5.2	0										
		4.7	0	5.1	0	5.1	8.6	7.2	1.4	51	1.418	7.21	.752	4.35	5.4
19	5½	7.5	0	8.0	0										
		7.4	0	7.9	0	8.0	9.2	7.4	1.8	56	1.658	8.43	1.020	7.00	6.3
31	5½	10.0	1.5	10.5	1.5										
		9.8	1.0	10.4	1.0	9.3	9.5	7.3	2.2	62	1.828	9.30	1.240	8.06	6.0
42	5½	13.0	2.8	13.0	2.7										
		13.3	2.8	13.2	2.7	10.4	9.6	7.4	2.2	52	2.180	11.10	1.770	8.60	4.5
7	6½	3.1	0	3.3	0										
		3.0	0	3.4	0	3.3	9.7	7.25	2.45	89	1.420	7.22	.752	2.55	3.1
20	6½	6.0	0	6.3	0										
		6.0	0	6.3	0	6.3	9.7	7.5	2.2	64	1.770	9.00	1.170	5.10	4.0
32	6½	8.5	2.0	9.0	2.0										
		8.0	2.0	8.5	2.0	6.8	9.4	7.3	2.1	56	1.930	9.82	1.390	5.40	3.6

TABLE I (cont'd)

Test No.	No. of Turns of Valve	Gage Readings: Gage No. 463 ft.	Gage Readings: Gage No. 458 ft.	Gage Readings: Gage No. 463 Corrected	Gage Readings: Gage No 458 Corrected	Gage Readings: Difference in Readings	Rod Readings: Initial ft.	Rod Readings: Final ft.	Rod Readings: Difference ft	Time Secs.	Discharge Cu.ft. per Sec.	Velocity Ft. per Sec.	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
43	$6\frac{1}{2}$	11.5	3.1	11.2	3.0										
		11.3	2.8	11.0	2.7	8.3	9.6	7.4	2.2	50	2.27	11.60	1.930	6.40	3.1
8	$7\frac{1}{2}$	3.0	0	3.2	0										
		3.0	0	3.2	0	3.2	9.45	7.45	2.0	64	1.610	8.18	.974	2.23	2.1
21	$7\frac{1}{2}$	5.2	0	5.5	0										
		5.2	0	5.5	0	5.5	9.4	7.4	2.0	56	1.840	9.36	1.260	4.20	3.1
33	$7\frac{1}{2}$	7.0	2.1	7.5	2.1										
		6.8	2.2	7.2	2.2	5.2	9.6	7.4	2.2	60	1.890	9.62	1.340	3.86	2.7
44	$7\frac{1}{2}$	9.9	3.9	9.8	3.8										
		9.7	3.5	9.6	3.4	6.1	9.6	7.5	2.1	48	2.26	11.50	1.900	4.20	2.1
9	$8\frac{1}{2}$	2.8	0	2.9	0										
		2.7	0	2.8	0	2.9	9.3	7.0	2.3	77	1.540	7.84	.891	2.00	2.1
22	$8\frac{1}{2}$	5.0	0	5.3	0										
		5.0	0	5.3	0	5.3	9.6	7.4	2.2	61	1.860	9.46	1.290	4.00	2.9
34	$8\frac{1}{2}$	5.9	2.3	6.2	2.3										
		5.8	2.3	6.1	2.3	3.8	9.6	7.4	2.2	54	2.100	10.70	1.650	2.15	1.2
45	$8\frac{1}{2}$	8.4	3.9	8.3	3.8										
		8.3	3.8	8.2	3.7	4.5	9.5	7.1	2.4	52	2.380	12.10	2.095	2.40	1.1
10	$9\frac{1}{2}$	2.3	0	2.3	0										
		2.4	0	2.4	0	2.4	9.5	7.0	2.5	82	1.572	8.00	.928	1.50	1.5
23	$9\frac{1}{2}$	4.6	1.8	5.0	1.8										
		4.5	1.8	4.9	1.8	3.2	9.6	7.4	2.2	60	1.890	9.61	1.34	1.86	1.3

TABLE I (cont'd)

Test No.	No. of Turns of Valve	Gage Readings: Gage No. 463 ft.	Gage No 458 ft.	Gage No 463 Corrected	Gage No 458 Corrected	Difference in Readings	Rod Readings: Initial ft.	Final ft.	Difference ft.	Time Secs.	Discharge Cu.ft. per Sec.	Velocity Ft. per Sec.	Loss in Friction in Pipe ft	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
35	9½	5.8	2.4	6.1	2.4										
		5.5	2.4	5.7	2.4	3.5	9.6	7.4	2.2	56	2.070	10.55	1.60	1.90	1.1
46	9½	7.8	3.9	7.8	3.8										
		7.7	3.8	7.7	3.7	4.0	9.5	7.3	2.2	50	2.270	11.60	1.93	2.10	1.0
12	12	2.1	0	2.1	0										
		2.2	0	2.2	0	2.2	9.4	7.0	2.4	80	1.548	7.86	.891	1.30	1.3
24	12	4.4	1.9	4.8	1.9										
		4.4	1.9	4.8	1.9	2.9	9.5	7.4	2.1	57	1.900	9.67	1.35	1.55	1.0
36	12	5.4	2.5	5.6	2.5										
		5.4	2.5	5.6	2.5	3.1	9.5	7.4	2.1	51	2.22	11.30	1.85	1.25	0.6
47	12	7.2	3.0	7.2	2.9										
		7.2	3.0	7.2	2.9	4.3	9.4	7.4	2.0	34	3.04	15.50	3.46	0.8	0.2

TABLE II
DATA SHEET for 6" VALVE
USING DIFFERENTIAL PRESSURE GAGE.

No. of Turns necessary to open valve = 12

$H = m\frac{v^2}{2g}$

Area of Pit = 51.54 sq.ft.; of Pipe = .1964 sq.ft.

Test No.	No. of Turns of Valve	Gage Readings R_1 ft.	Gage Readings R_2 ft.	Gage Readings Average ft.	Rod Readings Initial ft.	Rod Readings Final ft.	Rod Readings Difference ft	Time Secs.	Discharge cu.ft. per Sec.	Velocity Ft. per Sec.	Velocity Head $\left(\frac{v^2}{2g}\right)$	Loss in Friction in Pipe. ft	Loss in Valve ft	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
57	$1\frac{1}{2}$	5.7	6.9	6.3	10.6	7.6	3.0	468	.331	1.685	.045	.0396	6.3	140
61	$1\frac{1}{2}$	6.8	8.4	7.6	10.5	7.5	3.0	438	.354	1.800	.060	.0528	7.6	127
64	$1\frac{1}{2}$	1.8	2.4	2.1	10.5	7.5	3.0	541	.286	1.455	.035	.0308	2.1	60
65	$1\frac{1}{2}$	7.8	6.5	7.2	10.5	7.5	3.0	401	.386	1.965	.064	.0563	7.2	113
66	$1\frac{1}{2}$	6.4	7.6	7.0	10.5	7.5	3.0	407	.381	1.940	.060	.0528	7.0	117
73	$1\frac{1}{2}$	17.8	19.8	18.8	9.4	7.4	2.0	154	.669	3.400	.160	.140	18.7	117
81	$1\frac{1}{2}$	36.6	30.8	33.7	10.1	7.1	3.0	180	.860	4.370	.295	.260	33.4	113
89	$1\frac{1}{2}$	49.7	42.0	45.8	10.1	7.1	3.0	151	1.025	5.740	.510	.450	45.2	89
97	$1\frac{1}{2}$	28.9	34.8	31.8	9.6	7.6	2.0	124	.832	4.240	.280	.240	31.6	113
98	$1\frac{1}{2}$	31.0	37.1	34.1	9.3	7.3	2.0	119	.866	4.410	.300	.260	33.8	106?
99	$1\frac{1}{2}$	13.6	15.8	14.7	9.5	7.3	2.2	217	.523	2.660	.110	.100	14.5	132
107	$1\frac{1}{2}$	26.3	22.2	24.1	9.3	7.3	2.0	143	.721	3.670	.207	.180	23.9	115
115	$1\frac{1}{2}$	25.8	22.0	23.9	9.2	7.2	2.0	143.5	.719	3.660	.207	.180	23.7	114
58	3	1.6	1.2	1.4	10.6	7.6	3.0	415	.374	1.905	.060	.0528	1.4	23.4
62	3	1.0	0.6	0.8	10.5	7.5	3.0	600	.248	1.262	.025	.0220	0.8	32.0
67	3	1.0	1.2	1.1	10.5	7.2	3.3	348	.490	2.495	.096	.0844	1.1	11.5
74	3	14.8	13.0	13.9	8.35	6.95	1.4	56	1.285	6.56	.670	.590	13.3	19.9
82	3	24.4	21.1	22.8	9.0	7.1	1.9	61	1.605	8.19	1.04	.92	21.9	21.0
90	3	28.6	34.0	31.3	10.1	7.1	3.0	82	1.888	9.62	1.44	1.28	30.0	20.8
100	3	8.4	10.0	9.2	9.3	7.3	2.0	104	.992	5.05	.395	.34	8.9	26.2

TABLE II (cont'd)

Test No.	No. of Turns of Valve	Gage Readings R₁ ft.	Gage Readings R₂ ft.	Gage Readings Average ft.	Rod Readings Initial ft.	Rod Readings Final ft.	Rod Readings Difference ft.	Time Secs.	Discharge Cu.ft. per Sec.	Velocity Ft. per Sec.	Velocity Head $\frac{v^2}{2g}$	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
108	3	16.4	18.8	17.6	9.3	7.3	2.0	74	1.392	7.09	.78	.68	16.9	21.6
59	4½	0.5	1.0	.75	10.6	7.5	3.1	375	.427	2.175	.073	.068	0.68	9.3
63	4½	0.8	0.4	0.6	10.5	7.5	3.0	579	.267	1.36	.030	.0264	0.60	22.7
68	4½	0.7	0.5	0.6	10.5	7.5	3.00	378	.410	2.086	.070	.0616	0.60	9.7
75	4½	7.8	9.8	8.8	9.2	7.2	2.0	66	1.56	7.94	.98	.863	7.9	8.1
83	4½	15.5	13.4	14.5	9.3	7.2	2.1	57	1.90	9.66	1.45	1.28	13.2	9.1
91	4½	20.6	18.9	19.8	9.9	7.2	2.7	61	2.28	11.60	2.03	1.78	18.0	8.9
101	4½	6.5	7.4	6.9	9.3	7.3	2.0	77	1.34	6.825	0.72	.63	6.3	8.8
109	4½	9.9	11.6	10.7	9.3	7.3	2.0	61	1.691	8.605	1.16	1.01	9.7	8.4
60	6	0.2	0.4	0.3	10.6	7.6	3.0	288	.538	2.74	0.011	0.101	0.2	1.8
69	6	0.3	0.6	0.5	10.5	8.3	2.2	276	.408	2.08	0.070	0.062	0.4	5.7
76	6	5.6	4.8	5.2	9.5	7.3	2.2	66	1.74	8.75	1.18	1.04	4.2	3.6
84	6	10.0	8.5	9.3	9.5	7.2	2.3	55	2.16	11.00	1.88	1.65	7.6	4.0
92	6	13.5	11.8	12.6	9.7	7.2	2.5	51	2.53	12.89	2.51	2.25	10.3	4.1
102	6	3.6	4.4	4.0	9.3	7.3	2.0	68	1.516	7.72	.92	.80	3.2	3.5
110	6	6.4	7.3	6.8	8.9	6.9	2.0	54	1.910	9.73	1.47	1.28	5.6	3.8
70	7½	0.3	0.3	0.3	10.5	7.5	30	360	.430	2.19	0.08	0.704	0.3	3.7
77	7½	4.2	3.8	4.0	9.3	7.3	2.0	57	1.81	9.20	1.315	1.160	2.8	2.1
85	7½	7.0	6.4	6.7	9.3	7.3	2.0	47	2.195	11.19	1.91	1.68	5.0	2.6
93	7½	10.2	8.8	9.5	9.5	7.3	2.2	43	2.64	13.45	2.73	2.40	7.1	2.6
103	7½	2.6	3.2	2.9	9.3	7.3	2.0	66.5	1.550	7.89	.97	.84	2.2	2.3

TABLE II (cont'd)

Test No.	No of Turns of Valve	Gage Readings R₁ ft.	Gage Readings R₂ ft.	Gage Readings Average ft.	Rod Readings Initial ft.	Rod Readings Final ft.	Rod Readings Difference ft.	Time Secs.	Discharge Cu.ft. per Sec.	Velocity Ft. per sec.	Velocity Head $\frac{V^2}{2g}$	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
78	9	3.6	3.4	3.5	9.3	7.3	2.0	56	1.84	9.36	1.36	1.20	2.3	1.7
86	9	4.6	4.1	4.35	9.3	7.1	2.2	49	2.315	11.70	2.06	1.81	2.5	1.2
94	9	7.6	6.6	7.1	9.3	7.3	2.0	37	2.79	14.20	3.12	2.75	4.4	1.4
104	9	2.6	2.1	2.3	9.1	7.1	2.0	65	1.588	8.08	1.015	.88	1.4	1.4
112	9	3.4	4.0	3.7	9.2	7.2	2.0	51.5	2.005	10.20	1.56	1.36	2.4	1.8
79	$10\frac{1}{2}$	3.1	2.8	2.95	10.2	7.3	2.9	84	1.780	9.05	1.27	1.12	1.8	1.4
87	$10\frac{1}{2}$	4.6	3.9	4.25	9.3	7.1	2.2	49	2.315	11.70	2.06	1.81	2.4	1.2
95	$10\frac{1}{2}$	6.6	5.4	6.0	9.3	7.3	2.0	37	2.790	14.20	3.12	2.75	3.3	1.1
105	$10\frac{1}{2}$	2.3	1.8	2.0	9.3	7.3	2.0	64	1.610	8.195	1.04	.88	1.1	1.1
113	$10\frac{1}{2}$	2.9	3.4	3.15	9.2	7.2	2.0	50.5	2.042	10.40	1.57	1.37	1.8	1.2
80	12	3.0	2.8	2.9	9.8	7.3	2.5	71	1.82	9.26	1.33	1.51	1.4	1.0
88	12	4.6	3.8	4.2	9.3	7.2	2.1	46	2.465	12.52	2.36	2.08	2.1	0.9
96	12	6.2	5.3	5.75	9.3	7.3	2.0	37	2.790	14.20	3.12	2.75	3.0	1.0
106	12	2.3	1.8	2.0	9.3	7.3	2.0	61	1.691	8.605	1.16	1.01	1.0	0.9
114	12	2.8	3.3	3.05	9.2	7.2	2.0	51.	2.022	10.30	1.565	1.36	1.7	1.3

TABLE III
DATA SHEET for 8" VALVE
USING DIFFERENTIAL PRESSURE GAGE

No. of turns necessary to open valve = 16

Area of Pit = 51.54 sq.ft.; of Pipe =

$H = m\frac{v^2}{2g}$

Test No.	No. of Turns of Valve	Gage Readings R_1 ft.	Gage Readings R_2 ft.	Gage Readings Average ft.	Rod Readings Initial ft.	Rod Readings Final ft.	Rod Readings Difference ft.	Time Secs.	Discharge Cu.ft. per sec.	Velocity Ft. per sec.	Velocity Head $\frac{v^2}{2g}$	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	2	24.2	28.5	26.35	10.0	7.5	2.5	97.0	1.33	3.81	.22	.03	26.3	120
13	2	32.0	38.0	35.0	10.0	7.5	2.5	87.5	1.47	4.21	.28	.04	35.0	125
29	2	12.0	14.1	13.05	10.0	7.5	2.5	146.0	.884	2.53	.10	.01	13.0	130
36	2	2.9	2.6	2.75	9.5	8.5	1.0	124.0	.416	1.19	.02	.00	2.6	130
41	2	6.7	7.4	7.05	9.8	8.8	1.0	76.5	.675	1.935	.06	.00	7.0	117
6	4	11.4	13.2	12.3	10.0	7.5	2.5	60.0	2.15	6.15	.59	.08	12.2	20.7
14	4	15.2	17.6	16.4	10.0	7.5	2.5	52.0	2.48	7.10	.78	.09	16.3	20.9
22	4	19.3	22.8	21.05	10.0	7.5	2.5	46.5	2.77	7.93	.98	.13	20.9	21.3
30	4	20.5	23.9	22.2	10.0	7.5	2.5	46.0	2.80	8.02	1.00	.13	22.1	22.1
37	4	0.7	0.7	0.7	10.0	9.0	1.0	106.5	0.485	1.39	.03	.00	0.7	23.4
43	4	11.7	13.5	12.6	9.5	7.5	2.0	48.0	2.15	6.15	.59	.08	12.5	21.2
7	6	5.8	5.4	5.6	10.0	7.5	2.5	50.5	2.55	7.31	.83	.11	5.5	6.6
15	6	6.5	7.7	7.1	10.0	7.5	2.5	45.0	2.86	8.19	1.04	.14	7.0	6.7
23	6	8.3	9.8	9.05	10.0	7.5	2.5	41.0	3.14	9.00	1.26	.17	8.8	7.0
31	6	9.0	10.3	9.65	10.0	7.5	2.5	38.0	3.49	10.00	1.55	.21	9.4	6.1
38	6	1.3	1.3	1.3	9.5	7.5	2.0	87.5	1.18	3.38	.18	.02	1.3	7.2
44	6	2.0	2.0	2.0	9.5	7.5	2.0	70.0	1.47	4.21	.28	.04	2.0	7.1
8	8	1.4	1.4	1.4	10.0	7.5	2.5	48.0	2.68	5.67	.50	.07	1.3	2.6
16	8	3.0	3.4	3.2	10.0	7.5	2.5	43.5	2.96	8.48	1.11	.15	3.0	2.7
24	8	3.4	3.9	3.65	10.0	7.5	2.5	39.0	3.31	9.46	1.39	.15	3.5	2.5

TABLE III (cont'd)

Test No.	No. of Turns of Valve	Gage Readings R₁ ft.	Gage Readings R_2 ft.	Gage Readings Average ft.	Rod Readings Initial ft.	Rod Readings Final ft.	Rod Readings Difference ft.	Time Secs.	Discharge Cu. ft. per Sec.	Velocity Ft. per sec.	Velocity Head $\frac{V^2}{2g}$	Loss in Friction in Pipe ft.	Loss in Valve ft.	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
32	8	4.0	4.6	4.3	9.5	7.5	2.0	29.5	3.50	10.0	1.55	.21	4.1	2.6
39	8	0.9	0.9	0.9	9.5	7.5	2.0	66.5	1.55	4.44	.305	.04	0.9	2.9
17	10	1.6	1.6	1.6	10.0	7.5	2.5	41.5	3.11	8.91	1.23	.16	1.4	1.1
25	10	1.8	1.8	1.8	10.0	7.5	2.5	37.5	3.44	9.85	1.51	.16	1.6	1.0
33	10	2.2	2.2	2.2	9.5	7.5	2.0	29.5	3.50	10.00	1.55	.21	2.0	1.3
40	10	0.5	0.5	0.5	9.5	7.5	2.0	65.5	1.58	4.53	.32	.04	0.5	1.6
10	12	-0.1	-0.1	-0.1	10.0	7.5	2.5	47.0	2.74	7.85	.96	.13	0.0	0.0
18	12	0.9	0.9	0.9	10.0	7.5	2.5	41.0	3.14	9.00	1.26	.17	0.7	0.6
26	12	0.7	0.7	0.7	10.0	7.5	2.5	37.5	3.44	9.85	1.51	.16	0.5	0.3
34	12	1.2	1.2	1.2	9.5	7.5	2.0	29.5	3.50	10.00	1.55	.21	1.0	0.6
11	14	-0.5	-0.5	-0.5	10.0	7.5	2.5	47.0	2.74	7.85	.96	.13	0.0	0.0
19	14	0.5	0.5	0.5	10.0	7.5	2.5	41.5	3.11	8.91	1.23	.16	0.3	0.2
27	14	0.1	0.1	0.1	10.0	7.5	2.5	37.5	3.44	9.85	1.51	.16	0.0	0.0
35	14	0.6	0.6	0.6	9.5	7.5	2.0	29.5	3.50	10.00	1.55	.21	0.4	0.3
12	16	-0.6	-0.6	-0.6	10.0	7.5	2.5	47.0	2.74	7.85	.96	.13	0.0	0.0
20	16	0.3	0.4	0.35	10.0	7.5	2.5	41.0	3.14	9.00	1.26	.17	0.2	0.2
28	16	-0.1	-0.1	-0.1	10.0	7.5	2.5	37.3	3.46	9.91	1.53	.20	0.0	0.0

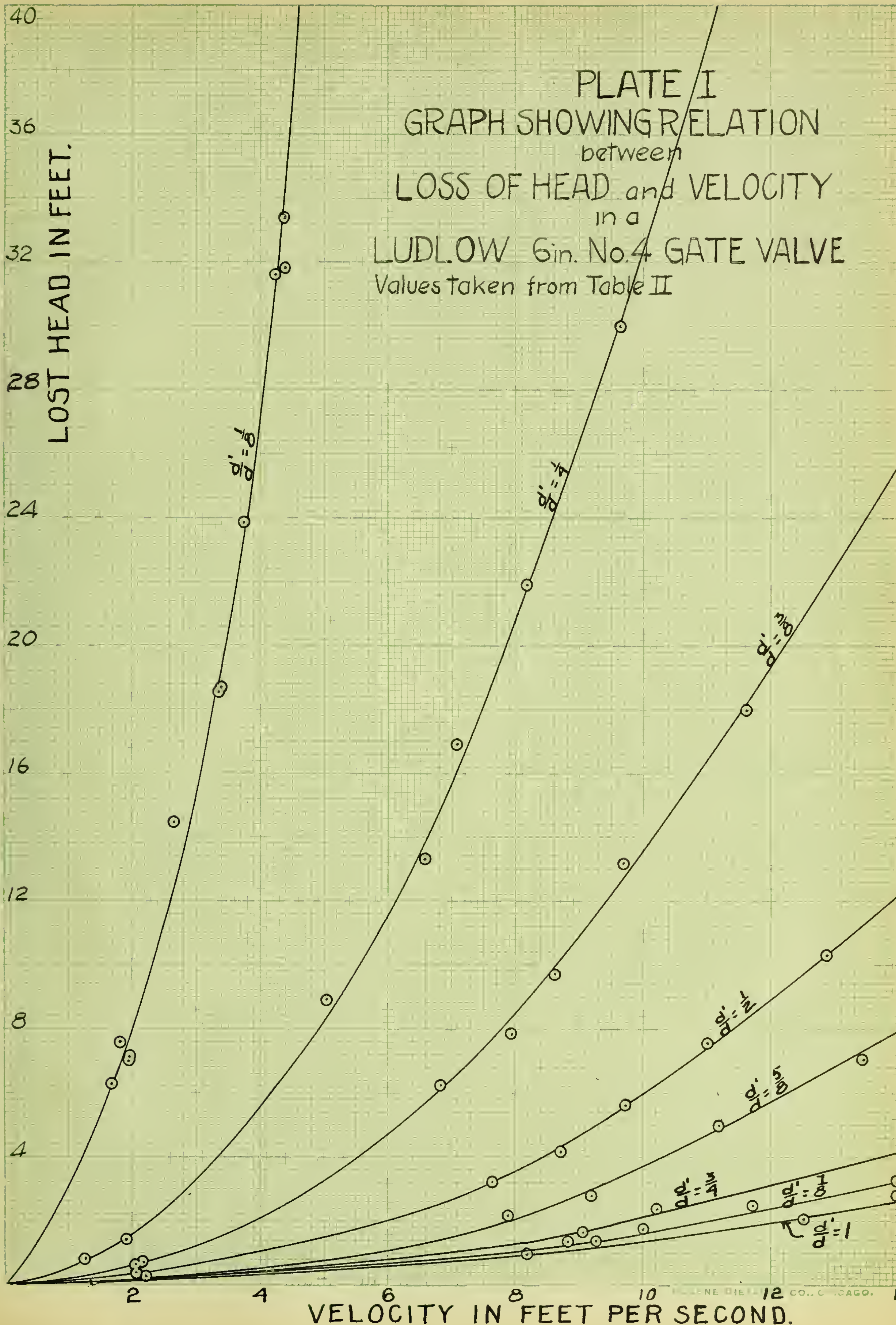


PLATE I
GRAPH SHOWING RELATION
between
LOSS OF HEAD and VELOCITY
in a
LUDLOW 6in. No. 4 GATE VALVE
Values taken from Table II
LOST HEAD IN FEET.
VELOCITY IN FEET PER SECOND.
40
36
32
28
24
20
16
12
8
4
2
4
6
8
10
12
14
d'/d = 1/8
d'/d = 1/4
d'/d = 3/8
d'/d = 1/2
d'/d = 5/8
d'/d = 3/4
d'/d = 7/8
d'/d = 1

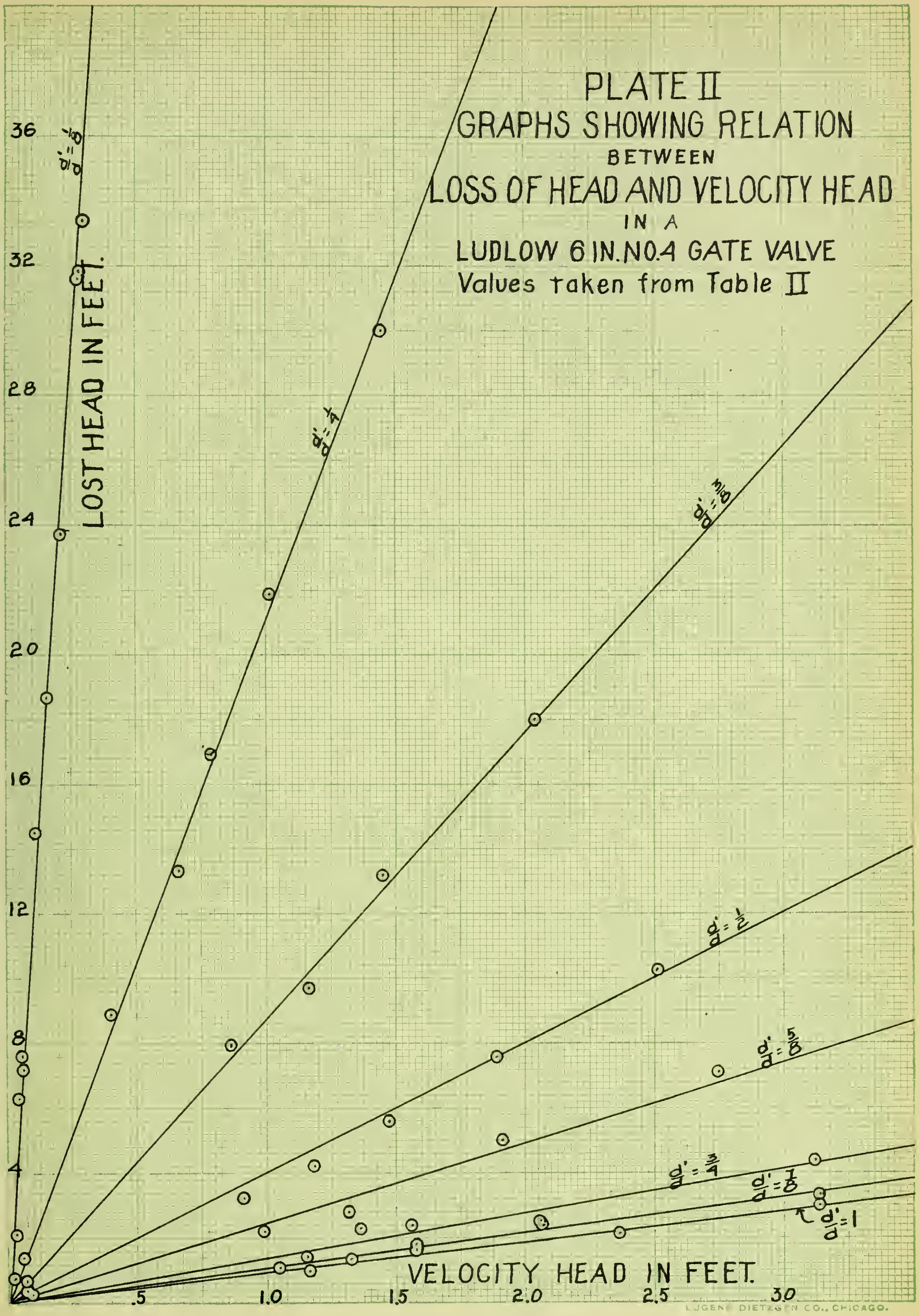


PLATE II
GRAPHS SHOWING RELATION
BETWEEN
LOSS OF HEAD AND VELOCITY HEAD
IN A
LUDLOW 6 IN. NO. 4 GATE VALVE
Values taken from Table II
LOST HEAD IN FEET.
VELOCITY HEAD IN FEET.
d'/d = 1/8
d'/d = 1/4
d'/d = 3/8
d'/d = 1/2
d'/d = 5/8
d'/d = 3/4
d'/d = 7/8
d'/d = 1
36
32
28
24
20
16
12
8
4
.5
1.0
1.5
2.0
2.5
3.0
EUGENE DIETZGEN CO., CHICAGO.

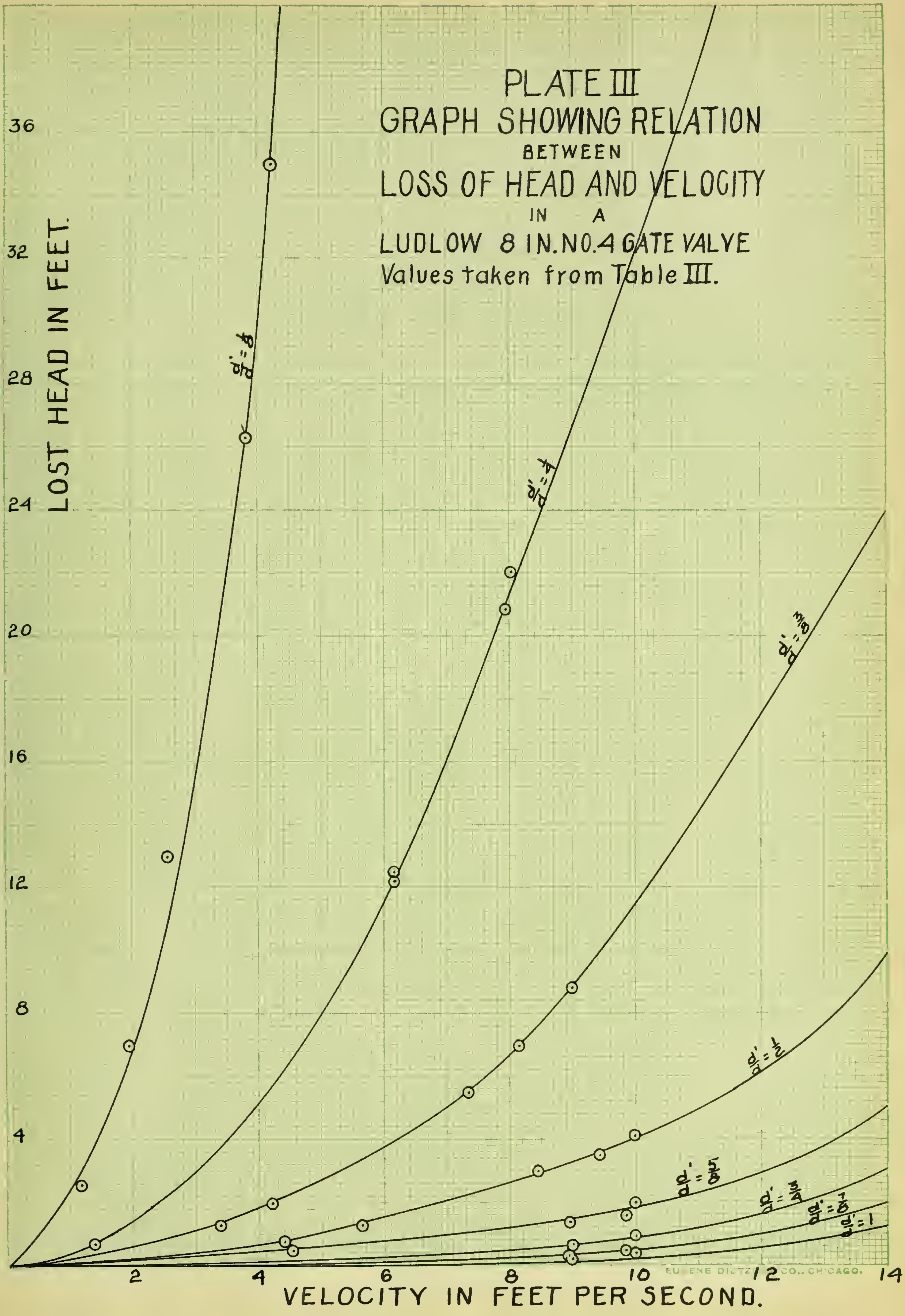


PLATE III
GRAPH SHOWING RELATION
BETWEEN
LOSS OF HEAD AND VELOCITY
IN A
LUDLOW 8 IN. NO. 4 GATE VALVE
Values taken from Table III.
LOST HEAD IN FEET.
VELOCITY IN FEET PER SECOND.
36
32
28
24
20
16
12
8
4
2
4
6
8
10
12
14
d'/d = 1/8
d'/d = 1/4
d'/d = 3/8
d'/d = 1/2
d'/d = 5/8
d'/d = 3/4
d'/d = 7/8
d'/d = 1
EUGENE DIETZGEN CO., CHICAGO.

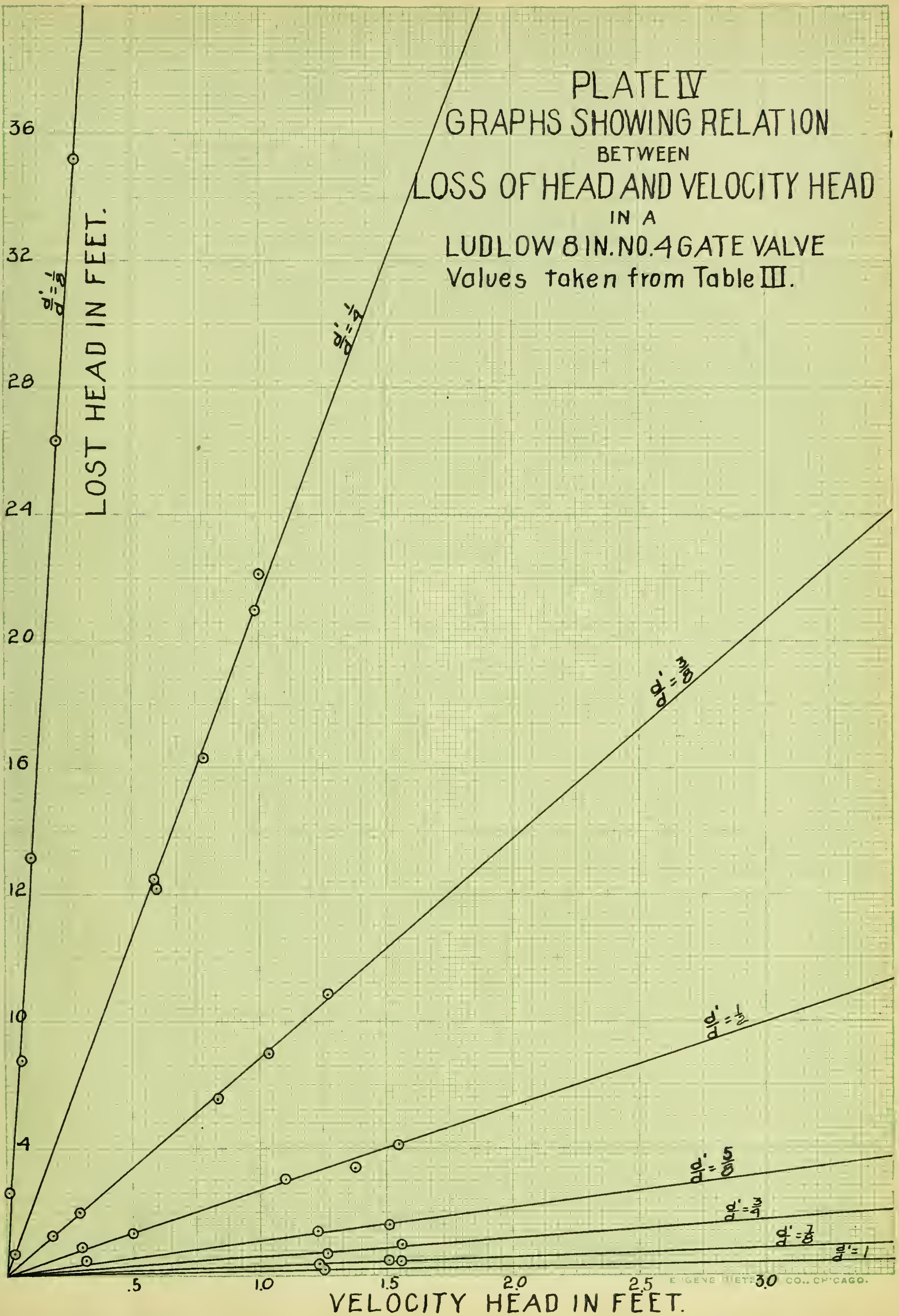


PLATE IV
GRAPHS SHOWING RELATION
BETWEEN
LOSS OF HEAD AND VELOCITY HEAD
IN A
LUDLOW 8 IN. NO. 4 GATE VALVE
Values taken from Table III.
LOST HEAD IN FEET.
VELOCITY HEAD IN FEET.
36
32
28
24
20
16
12
10
4
.5
1.0
1.5
2.0
2.5
3.0
d'/d = 1/8
d'/d = 1/4
d'/d = 3/8
d'/d = 1/2
d'/d = 5/8
d'/d = 3/4
d'/d = 7/8
d'/d = 1
EUGENE DIETZGEN CO., CHICAGO.

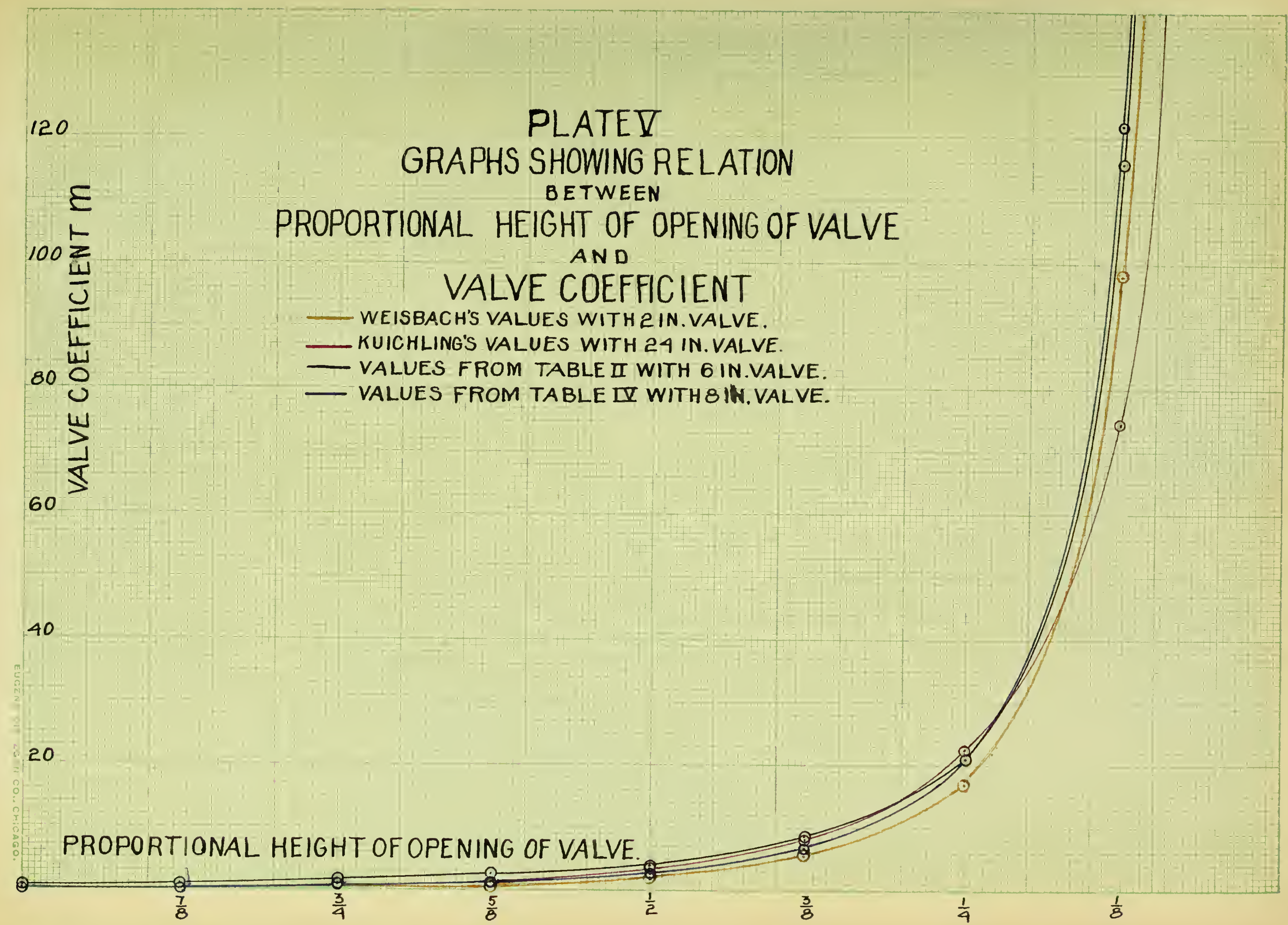


PLATE V
GRAPHS SHOWING RELATION
BETWEEN
PROPORTIONAL HEIGHT OF OPENING OF VALVE
AND
VALVE COEFFICIENT
WEISBACH'S VALUES WITH 2 IN. VALVE.
KUICHLING'S VALUES WITH 24 IN. VALVE.
VALUES FROM TABLE II WITH 6 IN. VALVE.
VALUES FROM TABLE IV WITH 8 IN. VALVE.
VALVE COEFFICIENT m
120
100
80
60
40
20
PROPORTIONAL HEIGHT OF OPENING OF VALVE.
7/8
3/4
5/8
1/2
3/8
1/4
1/8